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Quantitative Imaging of ^{177}Lu in the Presence of ^{90}Y for Peptide Receptor Radionuclide Therapy: A Simulation Study

Cassandra Miller[1,2], Carlos Uribe[3,4], Xinchi Hou[2,4], Arman Rahmim[1,2,3,4] and Anna Celler[4]

[1]Department of Physics and Astronomy, University of British Columbia, Vancouver, BC, CA
[2]Department of Integrative Oncology, BC Cancer Research Centre, Vancouver, BC, CA
[3]PET Functional Imaging, BC Cancer Research Centre, Vancouver BC, CA
[4]Department of Radiology, University of British Columbia, Vancouver, BC, CA

INTRODUCTION

Dual-isotope peptide receptor radionuclide therapy (PRRT) using ^{177}Lu- and ^{90}Y-DOTATATE is a promising treatment for neuroendocrine tumours.

30% of patients undergoing ^{177}Lu therapy may be undertreated[1]. **Personalized dosimetry** should be performed so the maximum dose can be delivered to the tumours while sparing healthy tissues.

Dosimetry of both ^{177}Lu and ^{90}Y can be performed using ^{177}Lu SPECT imaging, assuming identical biodistributions of ^{177}Lu- and ^{90}Y-DOTATATE.

However, **Bremsstrahlung photons created by ^{90}Y might cloud the ^{177}Lu spectrum**, making activity quantification inaccurate.

AIM

The aim of this work is to determine if quantitative SPECT imaging of ^{177}Lu in the presence of ^{90}Y is possible.

RESULTS

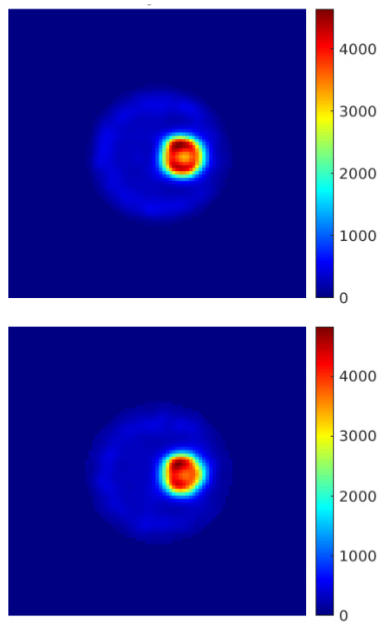


Figure 2: Reconstructed images
Top: 1.5 Mbq/ml ^{177}Lu + 0 MBq/ml ^{90}Y in the sphere, 0.15 MBq/ml ^{177}Lu in the phantom
Bottom: 1.5 Mbq/ml ^{177}Lu + 6 MBq/ml ^{90}Y in the sphere, 0.15 MBq/ml ^{177}Lu + 0.6 MBq/ml ^{90}Y in the phantom
Both isotopes were in sphere A.

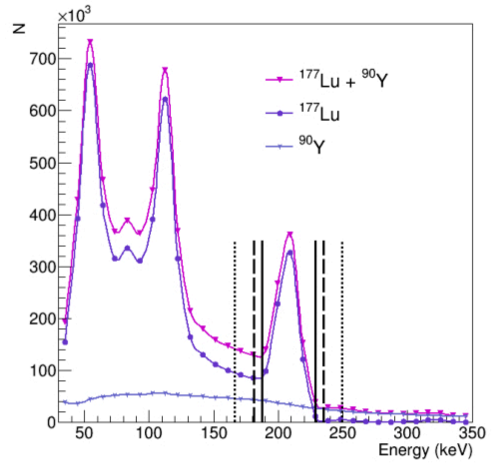


Figure 3: Energy spectra simulated with GATE as would be acquired by the SPECT camera. The dashed and dotted lines show the location of the 3% and 10% scatter windows, respectively. The solid lines show the location of the photopeak window. The activities of ^{177}Lu and ^{90}Y were both 16.6 MBq and there was 46.2 MBq of each in the phantom.

QUANTIFICATION

When the activity of ^{177}Lu was held fixed, adding ^{90}Y **decreased** the quantitative error (Figure 5a)

→ This is the opposite of what was expected; it was thought adding ^{90}Y would cause activity overestimation

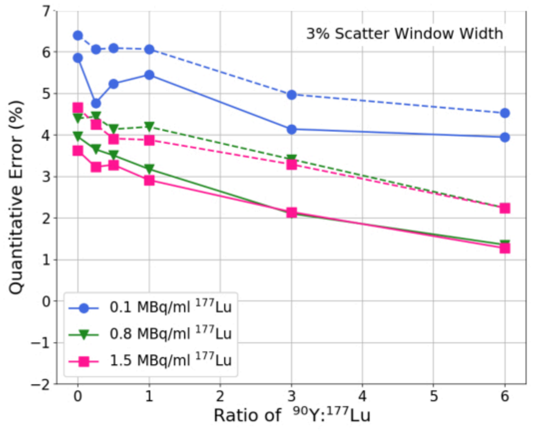
This phenomenon occurred because **^{90}Y reduces errors** associated with the TEW scatter correction method

→ Scatter correction and therefore activity quantification became slightly **more accurate** when ^{90}Y was present

NOISE

CNRs were not significantly impacted by the amount of ^{90}Y (Figure 5b)

→ In every configuration, the CNR was above the threshold of 5 suggested by the Rose criterion



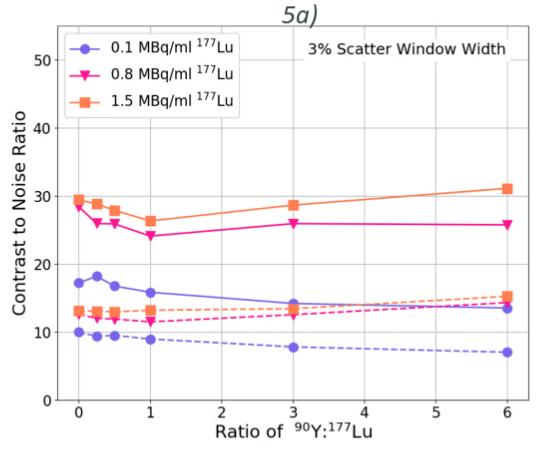


Figure 5 a) Quantitative errors (left-top) and b) contrast to noise ratios (left-bottom). Both isotopes were in sphere A. The dashed lines show when the activity concentration in the cylinder was 5 times lower than the concentration in the spheres, and the solid lines show when the activity concentration in the cylinder was 10 times lower than the concentration in the spheres.

SCATTER WINDOW WIDTHS

We found statistically significant ($p < 0.001$) differences in *E* and *CNR* between the large and narrow window widths

→ Quantitative errors were slightly better when a **narrower window width** was used

→ CNRs were generally better when the **wider window width** was used

METHODS: SIMULATION

Monte Carlo GATE software was used to simulate **3.3 cm radius spheres** filled with ^{177}Lu (range: 0.1 – 1.5 MBq/ml) and/or ^{90}Y (range: 0 – 9 MBq/ml) placed in a **20 cm x 20 cm cylindrical water phantom** which was also filled with a uniform activity of each isotope, either 5 times lower or 10 times lower than the activity in the spheres (Figure 1).

540 total simulations were created by varying the sphere/background activity concentration and the ^{90}Y location; 5 realizations were simulated for each configuration.

A narrow (3%) and a large (10%) **scatter window width** for triple energy window (TEW) scatter correction[2] was investigated.

Each configuration was imaged with a simulated Siemens MELP SPECT camera.

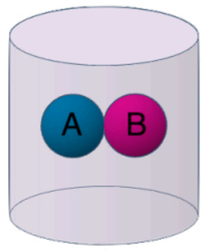


Figure 1: Schematic representation of the phantom containing two 3.3 cm radius spheres. Sphere A was always filled with ^{177}Lu. ^{90}Y was either placed in sphere B or in sphere A mixed with ^{177}Lu. This was done to determine if altering the location of ^{90}Y affects ^{177}Lu quantification.

METHODS: ANALYSIS

Projections were reconstructed using 3D OSEM with 8 subsets and 8 iterations with scatter correction, attenuation correction, and resolution recovery.

For **segmentation**, a 3.5 cm radius spherical VOI was placed over sphere A, which was always filled with ^{177}Lu.

Image counts were converted to an **activity** using a calibration factor derived from a scan of a ^{177}Lu point source.

The **quantification error** (*E*) and **contrast to noise ratio** (*CNR*) was determined for every configuration.

$$E = \frac{1}{R}\sum_{r=1}^{R}\frac{A_{est,r} - A_{true}}{A_{true}} \times 100\%$$

$$\mathrm{CNR} = \frac{1}{R}\sum_{r=1}^{R}\frac{\left(\frac{M_{voi,r} - M_{bkg,r}}{M_{bkg,r}}\right)}{\left(\frac{\sigma_{bkg,r}}{M_{bkg,r}}\right)}$$

R = number of realizations (5), A_{true} = activity simulated in the sphere with GATE, A_{est} = estimated activity in the sphere post-reconstruction, M_{voi}/M_{bkg} = mean number of counts in the VOI or background region respectively (the background region was a 3.5 cm radius sphere placed in the phantom under the VOI), σ_{bkg} = standard deviation of counts in the background region

CONCLUSIONS

Image quantification for ^{177}Lu remains within 8% even when very large amounts of ^{90}Y are used.

^{90}Y may slightly increase accuracy of activity quantification because of a reduction of errors associated with the TEW scatter correction method.

The presence of ^{90}Y does not significantly impact image noise.

Quantitative imaging of ^{177}Lu in the presence of ^{90}Y is feasible with high accuracy and no reduction of lesion detectability.

ACKNOWLEDGEMENTS

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CONTACT INFORMATION

Cassandra Miller (cassandramiller@phas.ubc.ca)
Arman Rahmim (arman.rahmim@ubc.ca)
Quantitative Radiomolecular Imaging & Therapy (Qurit) Lab (www.qurit.ca)